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On Active Passengering: Supporting In-Car Experiences

KOHEI MATSUMURA, Ritsumeikan University, Japan

DAVID S. KIRK, Northumbria University, UK

We describe the development of an interactive car window system designed to support passengers in engaging with the external environment during a journey. Through advances in embedded digital technologies, cars increasingly have a potential to become interactive spaces, in which passengers will find it possible to interact with the external environment through in-car interfaces. However the utility and benefit of such interactive systems for passengers has not been well studied. There is a need therefore, to study the design and use of these technologies, as they are emerging. We thus investigated how digital technology might support passengers' interactions with the external environment. Through a focus group (n=6) and interviews (n=5) we investigated passengers' attitudes towards, and practices during, ordinary car journeys. From this scoping study we formulated five design considerations for designing/implementing a prototype interactive car-window system. This system was then evaluated through an in-lab user study (n=8). Qualitative thematic analysis of interviews during the user study suggested a variety of orientations towards 'passengering', the act of being a passenger, on a journey. Herein we critically examine the role of our interactive technology in supporting desired experiences of 'active passengering'.

CCS Concepts: • **Human-centered computing** → **User centered design**; *HCI design and evaluation methods*; *Interaction devices*; *Ubiquitous and mobile computing*;

Additional Key Words and Phrases: in-car interaction, passenger, driving, mobility

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1 INTRODUCTION

The average driver spends 101 minutes driving every day (614 hours/year) in the US [7] and 39 minutes (235 hours/year) in the UK [5]. This implies that cars are indispensable in our daily lives. The popularisation of the car and increasing time that drivers spend in them attracts manufacturers and researchers to invest heavily in developing new in-car digital technologies such as navigation and entertainment systems. Such research supports drivers and passengers, improving their driving experience through purportedly increased efficiency and enjoyment.

Thanks to these digital technologies, the car is increasingly changing its role. No longer merely addressing issues of mobility the car now provides a place for communication, information access and/or the consumption of digital media. In this context, Human-Computer Interaction (HCI) research on in-car interaction has a significant role to play in advancing the in-car user experience, as Schmidt et al. argue “*As most of the technology in the car is digital, cars have become interactive spaces and human factors play a central role in their design and the resulting user experience*” [35].

Car manufacturers are also seeking to explore new roles for the car. Increasingly they are considering car interiors as interactive spaces. For example, Toyota in collaboration with the Copenhagen Institute of Interaction Design

Authors' addresses: Kohei Matsumura, Ritsumeikan University, College of Information Science & Engineering, 1-1-1 Nojihigashi, Shiga, Kusatsu, 525-8577, Japan; David S. Kirk, Northumbria University, School of Computer and Information Science, Newcastle upon Tyne, UK.

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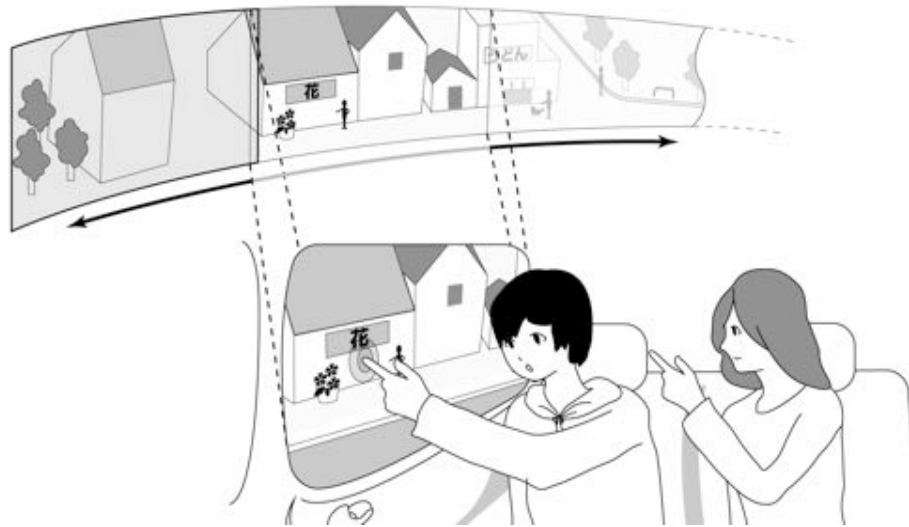


Fig. 1. An idea sketch of interactive car window. Passengers can interact with external environment through the car window.

(CIID) have illustrated concept designs for interactive car windows that enable passengers in a motor vehicle to interact with the world around them [38]. General Motors have also explored the possibilities of the car window [31]. Their concept, ‘The Windows of Opportunity,’ presented designs for an interactive window developed specifically for rear passengers. They also introduced the concept of car window ‘apps’ including an animated agent, finger drawing and a music player. Daimler’s concept car, the Mercedes-Benz F 015 Luxury in Motion, explores the possibilities of the self-driving car [1]. With the arrival of self-driving technology [5], the passenger experience is likely to fundamentally change. People will likely have time to do things other than driving during their journeys. Daimler have reconceptualised the motor car as a private retreat and a mobile living space. These three concepts for future cars all variously utilise the car windows as an interactive surface, postulating that this might be used to interact with elements of the external environment. However, the user experience of such interactive systems for passengers has not been well studied, and thus there is a need to better understand the design and use of these technologies as they are emerging.

In previous longitudinal studies, the first author investigated in-car conversations (over 10 months) and found that over 50 % of the topics were somehow related to locations external to the vehicle [27, 28]. This implies that the passenger naturally interacts with, and makes reference to, external objects/locations, and is talking about them with other passengers. Since self-driving technologies will inevitably free a passenger from driving, there will be even more opportunities for these kinds of interactions around external objects from the car. We thus began to study the possibilities for designing in-car interactions, which would support car passengers interacting with the outside scenery (the environment external to the car).

In this particular study, we try to answer the following research question by conducting a set of scoping studies, the subsequent design of a prototype in-car technology and an associated user study of that prototype.

RQ How can digital technologies help people to interact with the external environment through the car windows during a car journey?

1.1 Motivation for the study

Imagine the following four scenarios:

(1) *“Mom, what’s that building?”* During their drive, going out for their lunch, Mark, Heather and John’s son, is sitting on the back seat asking his mother about a building he sees. His curiosity is increasing day by day, and he is always asking about something that has caught his attention.

(2) *“Wait, what’s that? Stop the car... Did you see a strange blue thing passing by?”* Heather excitedly asks her husband, John. He replies *“Oh, did you see something strange? Are you asking me to make a U-turn to check it out?”* Something intriguing was seen, but the car has already passed by and they never grasp the details of it.

(3) *“Heather, could you find a restaurant near us? Oh, I see one over there. Is it good choice or...”* A family look for a nearby restaurant whilst driving. *“Wait, I’ll look up the restaurant on Yelp. Can I have the name of the one you just saw John?”* Heather uses her smart phone to look for reviews of the restaurant.

(4) *“How was your trip, Mark?”* After coming back home Mark’s grandmother asks him about their journey. He replies *“It was really nice. We saw some really cute squirrels from the car, climbing a tree!”* His grandmother, Louise replies: *“That’s nice... It’s a shame I couldn’t come with you. Did you get a picture of them?”* Mark responds *“Yeah... but it’s not a very nice picture, but you can see the tail of a squirrel here... we were just moving too fast to take a good one...”* *“Oh... It’s still cute though... Where did you find the squirrels?”* *“Dad, where was it?”* to which, John answers *“Let me think... I need to look at a map...”*

The above four examples are extremely mundane and commonplace interactions which might occur in-car, and yet they deserve our consideration as moments of interaction in which digital technology might offer support. Such examples motivated us to design our in-car interactive system. Obviously, we see an external environment through a car window or a windshield, but we wondered how we might reimagine that moment of interaction through the window. Fig. 1 (above) shows a concept sketch of an interactive car window. Using the window, passengers can interact with the external environment. The system allows passengers to freeze (i.e., pause/stop) the scene and rewind the outside view by buffering scenes for several seconds. The system expands the idea of Google Street View [10] with an intuitive user-interface and passenger supporting functions. This simple idea seemed promising, however, it was questionable without an underpinning theoretical framework and some understanding of how users would actually interact with and respond to such a system. We thus defined and began to explore the research question given above.

1.2 Study Contribution

We present the design of an interactive car window system that was developed from the results of an initial scoping study with car passengers. This explored passengers’ needs and activities during car journeys. We then present a fully working prototype based on our design. We then recount a user study that we conducted, discussing how people interact with the external environment using our prototype. This uncovers how in-car interactive systems should be designed and future directions for development. In particular we focus on the experience of ‘passenger’ critically examining notions of the ‘active passenger’, the ‘social passenger’, the ‘reflective passenger’ and concerns for the nature of ‘temporality and direct experience’ during car journeys. Additionally, we discuss some future directions expanding our use case from single-user to multi-user scenarios, helping to understand the future of networked autonomous vehicles [8].

2 RELATED WORK

Passenger Support. As automobiles are so imperative to our life, there have been a number of studies of in-car interfaces and interactions. For example [21, 35] who specifically focused on how to enhance in-car experience for drivers whilst ameliorating the risks of driving. However, the advent of self-driving technology makes driving

easier and will give a driver opportunities to do things other than driving during the journey. This implies a need to explore *passenger* support in the car.

Knobel et al. argued that “*Contemporary car design must not only focus on technology supporting the driver and the driving task: it needs to create positive experiences for drivers and passengers alike.*” [18] proposing several projects that aimed to enhance driver/passenger experience during car-journeys [18–20]. Their approach was not to be driver-centric nor focus on effective driving but make an effort after designing for positive in-car experiences. Following their call for creating positive experiences around in-car interaction we are dedicated to understanding interactions between passengers and the surrounding external environment of the car.

One study which has attempted to do just this, is Loehmann et al. [25] who proposed *The Periscope*, an interactive device, to support passengers in a car. This piece of technology is the most related to our work. They developed a form of interactive telescope that provides a passenger with the ability to explore interesting places around the car and share the experience with other (accompanying) passengers. Compared to their work, we aim to support passengers’ car journeys in a much more comprehensive manner. That is, we aim to enable passengers to interact with external environment not only just in the car but also after the car-journey. Several other studies have attempted to enhance in-car interactions in different ways. For example, using voice interaction, Misu et al. proposed *Townsurfer* an audio-based in-car assistant to provide information around a car [29, 30].

Interactive Car Window. In our work we are proposing an interactive car window. There are several related works on car window systems. For example, Li et al. prototyped an interactive car window system using a transparent LCD and explored interaction through the window [24]. They introduced their ideas to display active-notifications that indicate a user’s friend’s hypothetical location as well as three ever-present widgets indicating the time, temperature and the direction of the car on the window. Similarly, Hakkila et al. proposed a mixed reality concept car window [13]. Using a see-through display, they explored the possibility of enhancing the physical landscape with location-specific information. Also, there are several studies on windshield applications in the car. Haeuslschmid et al. discussed windshield interfaces as a design space through a comprehensive review of previous studies [12]. Our study also uses car windows as an interaction design space, but, through our scoping study and user testing, we focus mainly on understanding how digital technology helps people to interact with external scenery.

Finally, Yoshida et al. proposed a see-through wall system [39] that consists of a projector and screen, which is covered with retro-reflective materials [15]. This displays outside scenes that are captured by cameras, to assist the driver. That is, the driver can see, for example, objects behind the door, so that the driver can avoid collisions etc. Yoshida et al., evidently used car windows to increase car safety, alternatively to this, we were aiming to use car windows to enable passengers to interact with the external environment for either information seeking or entertainment purposes.

Recording and Reviewing Experiences. Our interactive window can record and document the experiences of a car-journey. There are a number of HCI studies concerning recording and reviewing experiences. Many of them are related to lifelogging i.e., studies of the quantified self. Lifelogging technologies enable us to mentally re-live in detail past experiences [37] and to help retrieve information about past events.

SenseCam is one well known lifelogging device [14]. It contains a number of sensors along with a wide-angle digital camera and is designed for a passive photo capture. Sellen et al. have argued that SenseCam data can support memory recall [36]. Kalnikaite et al. used location data (GPS) along with SenseCam and showed that multiple types of data, i.e., location data and photos, promote different acts of remembering [17]. Also, Lee et al. discussed how lifelogging technologies provide good memory cues for people with episodic memory impairments [22, 23].

The recorded and/or documented experiences of a car-journey with our interactive window system may help people understanding/remembering their past and this was a key consideration in our scoping study.

Despite above potential of lifelogging technologies, they have been criticised because of a lack of capacity for users to engage with the volumes of data they collect. Petrelli and Whittaker argued that digital family memorabilia

such as photos, videos and emails were rarely accessed [33, 34]. Choe et al. studied barriers to use lifelogging technologies and highlighted several common pitfalls including tracking too many things without triggers and context [3].

Our interactive window has the capacity to automatically record scenes outside of the car similar to a lifelogging device, however, in our design we focused on passengers' intent and desire to record and use an understanding of this in the design of the system.

3 METHODOLOGY

As described above, this study addresses the RQ, *How can digital technology help people to interact with the external environment during a car journey?* We approached the question by answering the following three sub-questions:

- 1). **Understanding current practices** In what ways do people currently interact with the external environment (through the car window) and how does this relate to passenger experience whilst in a car?
- 2). **System Design** What are the key technological functions that might help people to interact with the external environment and how might we implement those functions?
- 3). **User Study** How do people interact with the external environment using our prototype system, and how does this alter the passengers' experience?

Accordingly, we first wished to explore how people currently interact with the external environment from within the car. Commonly accountable activities observed, where people do this, include, for example, noticing and commenting on beautiful historic architecture, noticing the passing of the seasons by seeing deciduous trees, and/or counting cars in the oncoming lane. By trying to understand these kinds of interests and activities, we wished to elucidate design possibilities for our in-car system. We approached this endeavour through the development of a scoping study, consisting of a group workshop and accompanying participant-interviews.

From the results of this scoping study, we then presented the design of an interactive car window system. This was then implemented as a working prototype. The prototype itself foregrounds key functions and technologies that help to realise our design. Finally, we conducted a user study to evaluate our prototype and to investigate how our technology might help people to interact with the external environment from the car. Below we present each of these phases of work. We conclude with discussion of the way forwards for in-car technologies that support 'passenger' as an activity.

4 SCOPING STUDY: UNDERSTANDING 'CURRENT PRACTICES'

To understand '*current practices*', i.e. the current situation of how people interact with the external environment through the car window, we conducted a small scoping study. The scoping study consisted of two parts, a group workshop session followed by individual interviews. Eight people including two facilitators participated in the workshop. Our participants were of mixed gender (2F, 4M) and had different experiences with cars, some of them drove or were passengers daily and others had less frequent car use including not holding a driving license. They were aged from 23-32 years old and were from a variety of native countries including Egypt, Germany, Japan, Russia, Taiwan and the UK.

4.1 Group Workshop Session

The group session itself consisted of two parts. We first asked participants to watch a 20 minute video of a typical commuting car journey. Footage was obtained from a GoPro camera attached to the right hand-side rear passenger window of a car. Since the camera was attached to the car window at a mid-height (and roughly in-line with an average height passenger's eye-line from the rear seat), the point of view of the video footage was largely equivalent to the scene from the car seat.



Fig. 2. The route of the video footage. It includes two different situation, urban/residential area and motorways. ©OpenStreetMap contributors (<http://www.openstreetmap.org/copyright>)

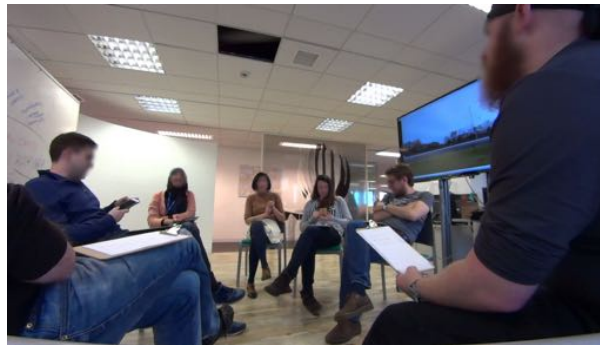


Fig. 3. The workshop discussion. Each participant shared their point of view on the video referring to their memo pad and remembered experiences of the video.

Fig. 2 shows the route of the video footage. The route includes two different driving conditions. One portion is in urban/residential areas and the other is a motorway scene. We gave each participant an A5 sized memo pad and a clipboard, and asked them to note down anything interesting that they found in the video (including a note of the time it happened). The video was played on a 60-inch LCD display and participants watched it with 2m–4m distances. For ease of noting the exact time of events we displayed a running time on the lower-right corner of the display.

After watching the video footage, the participants were invited to discuss what they had watched. Fig. 3 shows the setup of the session. We asked the participants to turn their chair and form a circle to make the atmosphere comfortable for discussion. We seeded the discussion with a question, “What kind of things did you see in the video that might be interesting to comment on?” The discussion lasted about 30 minutes. Each participant shared his/her point of view on the video referring to his/her memo pad and experiences that he/she remembered from earlier. Participants commonly grounded their observations in relation to their everyday experiences of being a passenger on car journeys. At times a facilitator questioned participants to help elucidate further reflection and insight on comments made to focus on the passenger experience.

4.2 Interviews

We also conducted individual semi-structured interviews with each of the workshop participants (bar one female who dropped out due to a scheduling conflict). During the interview session, participants were asked questions such as:

- If you are going on a long car journey, how do you prepare. (e.g. what would you take with you?)
- What kinds of technology would you take?
- What features of the external environment do you ever take note of when you are the passenger?
- Do you ever see things from the car window and want to remember them later?
- If you see something unfamiliar on a journey what would you do?
- If you saw something interesting through the car window and wanted to share it – how would you go about doing that?

In addition to these questions, the interviewer probed for deeper reflection as necessary to again, further elucidate interviewees experiences of passengering. Each interview lasted between 11.5 and 16.9 minutes (14.5 minutes in average).

4.3 Analysis

All sessions of the workshop were recorded by a voice-recorder with prior permission. The memo pad used in the group session were collected and ordered as a time-line. The recorded data of interviews and discussion were then transcribed and analysed by the two authors.

Our intention with the scoping study was to develop a preliminary set of understandings about the current experience of how people interact with the external environment through the car window, which could be used to help inform our system design. We used a relatively lightweight analysis method to summarise the data collected, deciding that a full Grounded Theory approach was unnecessary. Instead, we analysed transcribed data as described below: From the workshop/discussion, we selected typical scenes from the video journey, based on a set of criteria. The selection criteria were determined by two conditions, the number of people who had made a note on that video scene and whether the scene was actively discussed in the workshop or not. This ensured the unbiased selection of video scenes below. For the transcribed text obtained from the interviews, we made several passes through the transcription, hand-coding for themes of interest. After generating initial codes we compiled sub-themes into meta-themes using the affinity diagramming approach (i.e., KJ Method) [2], a commonly used technique in qualitative analysis.

5 SCOPING STUDY FINDINGS (WORKSHOP AND INTERVIEWS)

In the findings below we summarised the key points of interest raised during both our workshop and subsequent interviews with participants about their journeying experiences.

5.1 Workshop

During the workshop participants commented actively during the video viewing, with some 106 comments made during the 20min clip. In Table 1 we show shots from nine moments in the video where participants noticed reportedly interesting features. We have selected these nine on the basis that either at least three participants commented during the video playback or the clip was returned to during the open discussion after the viewing. Below, in Table 1 we work through each of the images in turn, providing summary information about the types of features of interest that the participants highlighted when commenting the clip.



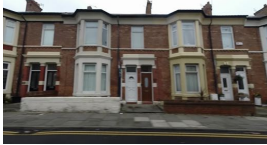






Clips	Descriptions
	Features of the external environment such as the weather, or features of the scenery (natural vegetation etc...).
	Features of the built environment, such as noticing the number of cars parked at a specific location (presumably in relation to normal levels of busyness) or commenting on the distance between vehicles.
	Wanting to know more about the area (including area names [40, 41]), more information such as how much buildings on a street were worth (domestic residences) or information about shops (opening hours etc.) and local amenities.
	Some commentary were more esoteric noticing features such as birds in the sky and wondering what the 'bird's eye' view was like.
	Discussion about iconic buildings wanting to know more about them specifically, such as their name, their history, their current and former uses.
	Unusual features of the outside environment – such as a piece of discarded carpet over some railings. Wanting to know why or how long it was there and being able to mark the space or tell others about it.
	Signage on vehicles, a desire to note the information, and record such details.
	In-car interaction with children wanting to know more about things they could see or who were engaged in games such as counting the number of silver cars they could see.
	Adverts on static boards wanting to record the information.

Table 1. Indicative scenes of external environment (through the window) engagement from the video footage.

5.2 Interviews

After the interviews were transcribed we analysed the text. Below we present some summative considerations (tied to our questions), demonstrating the types of experiences passengers were recounting to us (with indicative quotes from the interviews).

Managing boredom / being a good passenger. For some participants being a passenger involved balancing the management of boredom and support for the driver, as Participant 1 explained: “[he] always drives. So I’m always the passenger. So I always feel bad to use my phone, because then it’s boring for him because he has to drive. But then, usually, after a while, it gets boring anyway” (P1). In this context technology use was seen as both pro and anti-social but primarily for keeping oneself occupied.

Gadget use in-car. For most participants journeys were accompanied by the use of personal technologies. More often than not a mobile phone but sometimes other specialist devices: “Generally Kindle and I have my smart phone on me by default. [...] I store all my music via cloud and then pin it to my phone, so you don’t need the Internet connection. I would generally maybe as part of the preparation actually, [...] I would have loaded it up with a few albums or something.” (P4). Accordingly, participants routinely described ‘preparation’ of their digital resources to be consumed on a journey. For some there was a desire to capture media, such as photos but an acknowledgement that the available devices were not good for this on most journeys: “My phone. [...] To browse the Internet. I do take photos from the car but not very successfully, so I basically don’t. I use it for music a lot” (P5).

Taking an interest. Participants talked about a desire to document their journeys – often for others “Sometimes you take pictures and send it to the people there, it’s quite funny and say, ‘Look where I am’ ” (P1); but often there was an attempt to use technology to simply understand more about a place: “I wonder what that is. Just Googling places of interest if I am not driving.” (P2). And for a three of our participants there was an explicit desire to compare and contrast landscapes that they had driven through: “It depends where I am going to. Here in the UK for example the roads are usually quite interesting because you get many services around the roads, pubs or things like that. We went to Scotland and the nature is beautiful so you would definitely be looking at the forests, lakes, mountains etc. When I had trips in Italy it wasn’t that interesting.” (P3).

Recording sights. For many the means of recording interesting moments on a journey – on the relatively rare occasions that this did happen – revolved around specific technologies – which were often found to be troubling. Referring to GPS marking, Participant 2 stated: “I have dropped a pin, but then I can’t remember why I have dropped it there. I have got a map that has got some pins on, but I don’t know what they are there for” ; and referring to issues around photo capture he stated: “You are driving past it and you see a really nice place that you would like to photograph but you can’t really because you are speeding past it” and, “when you are in the moment you don’t want to be fumbling around with your phone” (P2). Again, for some this record would end up archived on social media,

“If I’ve passed something I might put a Facebook status up or a tweet, just saying, “I’ve seen this thing.” I think we passed a shop called the Button and Pug once and I was sitting trying to work out what was in it. I’m not sure if it was vets or tailors or tailors for dogs or something like that, but yes, like a tweet or a Facebook, whatever I’m feeling in the mood for.” (P4)

Unfamiliar sights. Of particular note was a more social attempt to engage with the environment in which our participants explained essentially crowd-sourcing their queries about the external environment: “We go, ‘Okay who has lived here?’ and I’d probably try and text them or message them in some other way to say, ‘Have you heard of this?’ If yes, then, ‘What’s the information on it?’ ” (P4). This suggests interesting potential for the crowd-sourcing of local information queries, whilst travelling.

6 INTERACTIVE CAR WINDOW SYSTEM

In response to the scoping study we developed an interactive car window system. Simply stated, the system allows users to interact with external environments through the window. We reflected our findings from the scoping study in the design as much as possible. This section describes features extracted from the findings and their implementation.

6.1 System overview / apparatus

Fig. 4 shows an overview of the system. The system supports two core features, *passenger* and *reviewing*, to help people interact with the external environment. The system consists of three main parts: a touch enabled Windows PC with camera, a web server, and a smartphone. Each of them communicates via the Internet. We used Microsoft Surface Pro 3 as the touch enabled Windows PC. This has 8GB memory and Intel Core i5 processor, and is capable of capturing the scene behind its 12 inch screen with a five megapixel rear-facing camera. It is also capable of connecting with an external display. Since the screen size of the PC seems too small for the car side window, we used an external 19.5 inch touch enabled display (ASUS VT207N) for the user study. We implemented the system as a Universal Windows Platform (UWP) application with C# language. The platform natively supports touch operation with multimedia functionality. The webserver receives clipped images from the PC (i.e., the interactive window system) and stores them on its database engine. The server also serves reviewing webpages. It allows users to review their journey using the web browser on their smartphones by simply accessing the server. We implemented the server using web.py framework¹ on the Google Cloud Platform. To implement some system functionality we used Google APIs such as Google Cloud Vision API [9] and Google Maps API.

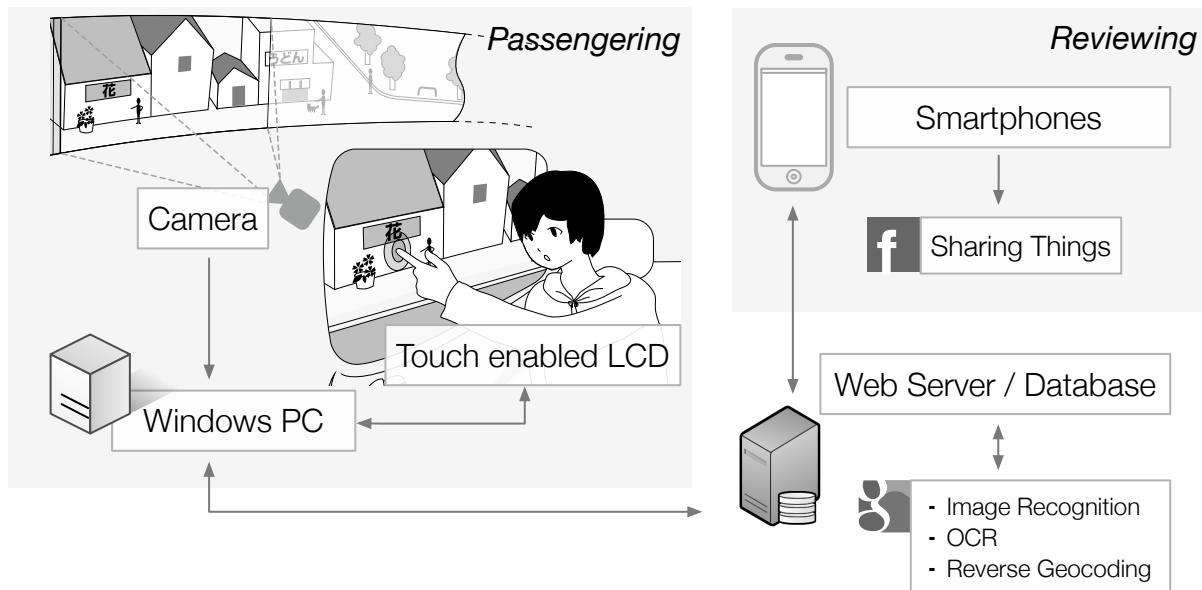


Fig. 4. Overview of our system. The system mainly consists of two parts. (1) *Passengering*, supports people to interact with the external environment during the car-journey; (2) *Reviewing*, supports people to reflect upon and to explore the external environment much more deeply after the trip.

¹<http://webpy.org>

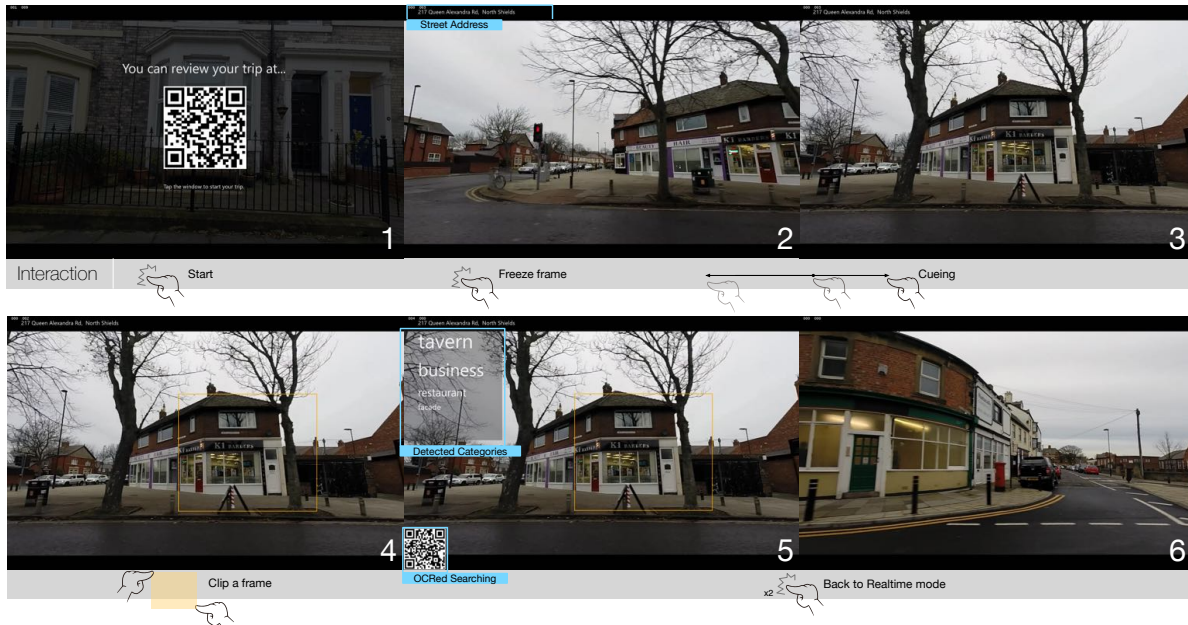


Fig. 5. Interaction flow of the system. A user starts their car-journey by tapping the window. The frame freezes when the user taps the window. The user can cue the scene using a swiping gesture. When a user clips a frame using a pinch gesture, the system provides the user with additional information. A double tap gesture finishes capture mode and switches back to real-time mode.

6.2 Passengering support

The *Passengering* support feature allows people to interact with the external environment during their car-journey. This consists of a touch enabled display and a camera and shows live external scenery to passengers through the display. It also provides several features including freezing the screen, turning back and clipping the image. That is, a passenger can interact with the external environment through the display. In addition to the camera and the touch-enabled display, the system also handles a GPS tracker. All the devices are connected to a controlling PC. The PC also communicates with the server on the Internet. The feature provides several interactions as shown in Fig. 5 and details are described below. This basic feature answers the theme ‘*Managing boredom / being a good passenger*’ extracted in the scoping study and supports passengers to manage their boredom. This interactive car window itself is for the passengers but it also supports a driver indirectly via passenger interactions. Passengers can ‘clip’ interesting scenes for the driver who might be intrigued by external scenes but who cannot look closely because they are concentrating on driving.

6.2.1 Access to reviewing support. The system firstly shows a QR-code (see Fig. 5.1) that navigates a user to a web-page that enables users to review their experience after the car-journey. We found that each participant took their mobile phone on their car journeys. We thus implemented this feature to bridge between the system and users. The reader may wonder why the QR-code should be shown at the end of the journey. However, since the car-journey may suddenly terminate when the driver stops the engine of the car, we decided to show it at the beginning of the trip. Once the user scans the QR-code, they can browse the reviewing webpage whenever they want. Another

possibility is that the users register their e-mail address with the system, so the system will be able to send an e-mail with a link to the reviewing website. It may depend on a user's preference, but our current implementation shows a QR-code at the beginning of a trip because our scoping study revealed that most participants carry smartphones during car-journeys.

6.2.2 External scene as a video. To enable passengers to interact with the external scene, we determined to develop a camera see-through window system. The system captures the external environment with a camera and passes it through to a touch enabled display (see Fig. 4). That is, passengers can see the external environment through the display. As you can see in Fig. 5.2, the passenger can freeze the external scene by utilising a tapping gesture. Also, the system shows street name/address on the left shoulder of the display to help remembering as some participants desired to know where they are, as one of the participants wrote "Where is this? Identify the street." (P7) on his memo pad. After freezing the scene the passenger can move back the external scene for up to ten seconds using a swiping gesture (Fig. 5.3). That is, the system buffers the camera stream for ten seconds and the passenger can manipulate it. This function provides the passengers opportunities to explore the detail of the external scene. This ten seconds limitation arises from the memory size of the buffer. Of course the buffer could be enlarged infinitely. However extending the buffer size may break the user's attention away from the real-time scene behind the display. Parameters for appropriate buffer size should be considered in future work. The system has another buffering function. Whilst the passengers are interacting with a frozen scene, the car is still moving. That means the passenger will miss chances to know what is happening outside of the car whilst interacting with frozen scene. To compensate this, the system provides quick playback of external scenes as time-lapse images. Several previous studies have tackled this kind of problem including [6, 16], accordingly we appropriated these ideas to implement the function. The time-lapse images are played when the passengers double-tapped the display; this returns the passenger to the *real-time* scene.

6.2.3 Clip external scenes. Reflecting the demands elicited in the interview, we implemented a feature that enables passengers to clip (i.e., record) elements of external scenes. While the system is showing a *frozen* external scene, the passengers can clip the scene by using a pinching gesture (see Fig. 5.4). While the passenger is performing this pinching gesture an orange rectangle is drawn out to show the clipping area.

To provide details of the clipped area, to the passenger, we send the clipped image to Google Cloud Vision API [9]. They send back the results of recognised categories and text and we put them on the screen. Fig. 6 shows examples. In the figure, recognised categories are shown on the left shoulder and text size is automatically calculated according to its possible relevance. Also, if the clipped image contains text, the system generates a QR-code that directly navigates the passengers to the result of the Google Search. That is, the passenger just scans the QR-code when he/she wants to get further information on the Internet. This function may support tourists, for example, who are unfamiliar with a place and who want to know more about a specific location [4]. Our scoping study specifically suggested that passengers often want to know information about a place they are journeying through: "*I wonder what that is. Just Googling places of interest if I am not driving.*" (P2). Additionally, clipped images and their metadata (i.e., categories, OCR text) are automatically stored in the database server. We setup the server on Google Cloud Platform.

6.3 Reviewing support

The *Reviewing* support feature provides passengers with opportunities to reflect upon their journey(s). As many of the participants showed a desire to document their journeys, the system automatically makes a summary of a journey and compiles them as webpages. This feature allows a passenger to remember their journey and to explore scenery that they found interesting during the journey. The *reviewing* features are provided by the web server and communicate directly with a smartphone.



Fig. 6. Three sample scenes. The system automatically recognises clipped image and shows the categories of the image. Also, the system provides QR code when it recognises there is text in the image.

Fig. 7 shows an example of a review page on a smartphone. A user can swipe up/down to see another clip. The page shows the clipped image as well as the location of the image on the map, its categories, recognised texts and the date/time. The map provides an exact location for each image and its surrounding information. The user can scroll, zoom in/out, and rotate the map. Similar to the passengering support feature, the user can search recognised texts on the Internet by clicking the search button if the image contains any text.

As we described above, participants also showed a desire to share their journeys with others (see “*Unfamiliar sights*” in §5.2). A user may ask someone if they are unfamiliar with a place, “Do you know what happened in this place?” for example. Accordingly, the webpage also has a sharing button. It enables users to directly share the image with others through social media (e.g. Facebook) by clicking the button.

7 USER STUDY

To understand “How people interact with the external environment using our system”, we conducted a user study in the lab. The study consisted of four stages; practice, passengering, reviewing and interview. A participant in the user study first watched a video detailing operation of the system, they then took three minutes to practice using the system with a facilitator on hand to answer questions. Then they started their ‘journey’ for seven minutes. The route of the journey was extracted from the route used in the previous workshop (see Fig. 2). The route consisted of three minutes on the motorway and four minutes in an urban area that included 1.67 minutes of congestion. Participants were encouraged to use the system as they wished during the journey, and also to ‘think aloud’ whilst using the system. After the journey, the passenger reviewed their journey on a smartphone for up to three minutes, looking at the items they had recorded. A semi-structured interview session followed where they were asked questions such as:

- What object did you capture (with the system) during the trip and why?
- Did you find something during the review session (on the phone) that you had not been aware of before?
- How might you use a system like this in a car?
- What would stop you from using a system like this?
- How might our in-car system change the experience of being a passenger?
- Do you think our system makes you more or less engaged with the external environment? Why and How?
- Did you have any problems or difficulties with using the system, if so what and why?
- Do you think there is any lacking or missing parts in the system? Are there any features we should add? If so, which, and how would you use them?

Eight people participated in the user study. Fig. 8 shows the setup of the user study. Each of them sat on the left-hand side of a 19.5 inch touch enabled display with a 50 cm distance as if they were passengers on the

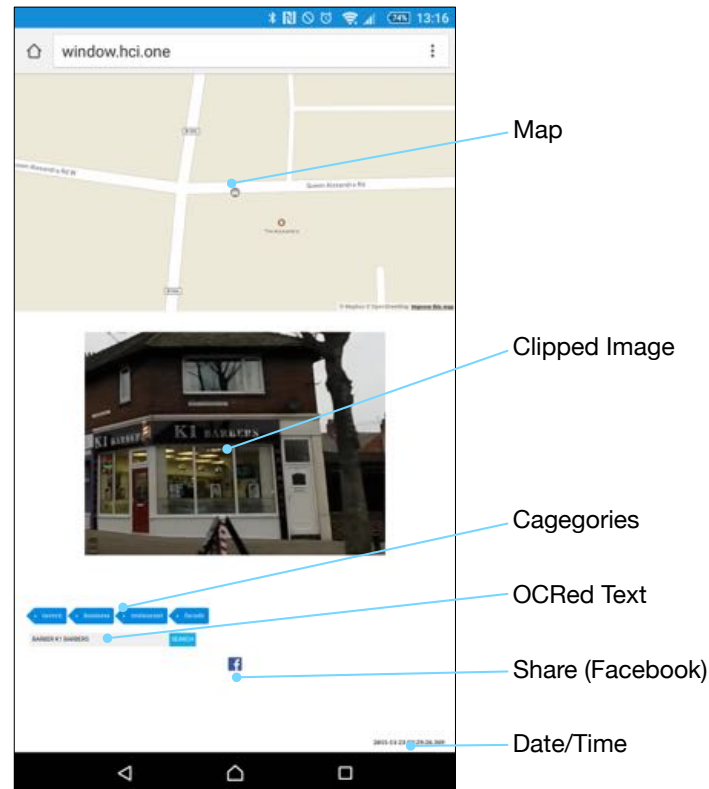


Fig. 7. An example of the reviewing page. This shows the location of the clipped image on the map as well as the clipped image, its categories and recognised texts. Also, the passenger can share the page on Facebook using the share button.

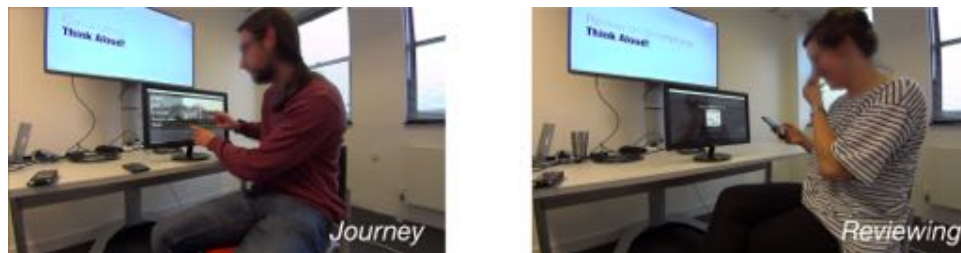


Fig. 8. Scenes of the user study in the journey session (Left) and the reviewing session (Right). Each participant sat in parallel with the display placed on the right-hand side of him/her.

right-hand side back-seat of a car. Participants had a variety of nationalities including Jordan, Korea, Russia and the UK. Note that none of the study participants had previously participated in our scoping study.

Through the passengering session, participants clipped 9.25 pictures on average (SD 5.44), 74 pictures in total. In the following we report on our thematic analysis of the user test interviews. The thematic analysis was performed

through the following process: (1) The two authors individually generated initial codes for the transcribed interview texts. (2) We then gathered these initial codes and discussed overlaps and discrepancies between the two authors to derive a set of common themes from the initial codes. (3) We finally reviewed the common themes and compiled them, defining higher order meta-themes. Looking to explore their experiences of the technology, and in particular focusing on our research questions of how people may interact with the external environment through it, we elicited four key themes that reflect specific aspects of ‘passengering’, the act of being a passenger in a vehicle. Table. 2 shows the extracted higher order themes through the analysis. We discuss each theme in turn below, providing illustrative quotes taken from our interviews.

<i>Common Themes</i>	<i>Higher Order Themes</i>
<ul style="list-style-type: none"> • Exploring the outside world <ul style="list-style-type: none"> – Being curious • Putting information into the world • Normal passengering is passive • Passengers having a role in the car • Wanting specific information (about environment) 	Active passengering
<ul style="list-style-type: none"> • Reflecting on journeys • Documenting journeys <ul style="list-style-type: none"> – Taking photos – GPS mapping 	Reflective passengering
<ul style="list-style-type: none"> • Possibilities for gaming in-car • Being social within the car • Being social between cars • Supporting multiple users <ul style="list-style-type: none"> – Multiple screens and views 	Social passengering
<ul style="list-style-type: none"> • Changing natural of temporal engagement • Alleviating boredom • A concern for ‘direct experience’ of the world 	Temporality and direct experience whilst passengering

Table 2. The results of our thematic analysis. We extracted four higher order themes from the analysis.

7.1 Active Passengering

In various ways our participants explained how the technology we had designed might lead to a more engaged, active passenger experience. This was starkly juxtaposed against what they felt was the more normal *passive state of passengering*. For example “*This isn’t something you normally get as a passenger, you accept that ‘stuff’ happens around you*” (P6); “*I probably desensitise to what’s around me, as I just do it over and over again*” (P4); and “*there’s particular buildings that look interesting but I don’t know what they are and I’ve never known and I’ve never bothered to look*” (P8).

For some participants there was a clear sense that a technological intervention was useful because it might in some way give passengers more of *a role within the car and on the journey*, “*It gives you something to do, maybe giving more of a role to the passenger. It gives you an explicit task*” (P6); “*It also makes me feel like a volunteer helping to create a meaningful maps content*” (P7). This latter point in particular stemmed from a desire

to explicitly use the system *to input information into the world* (rather than just explicitly ‘reading’ the external environment). For example, “Yes. I think I’d want to put the pictures that I’d taken into the world” (P1); and “You might call it even volunteering to enrich the world with details about our places around us” (P7). As Participant 7 further explained:

“After I tag something, I would like to put some details what it is; so instead of waiting for the system to capture this as a megastore, Tesco, or something like this, then I prefer to do it myself [...] [if] I find that it is wrong, then I can actually just go and correct it directly.” (P7)

For many participants the actual value of the system however, was the way in which it prompted an *exploration of the world outside* of the car. Participants suggested things like: “It will make me be more active passenger through connecting with outside context of the car” (P5); “Being more engaged with what’s happening around you” (P6); and “I found myself looking out of the window much more actively than I think I usually do, as a passenger, and I suppose less passive, and actually seeking out interesting things” (P8). For some this was very tied to explicit technical features of the system for example Participant 2 claimed “knowing that it has an OCR element, makes me as a passenger, on the lookout for titles and signs” (P2).

Such explorative considerations were similar to those who felt the system should support their *wanting specific information* about the environment: “I guess I wanted some more information on that gym, which is on the way home” (P4); and, “I think when it’s on it would be useful to have much richer information like text overlaid on the screen and more places that you can click” (P1). However, for some the system was a support for their *being curious* about the world, “It’s a different level of engagement – an enquiry about things, giving you the tools to look further” (P6); “The restaurant was because I was curious. I walk by that as well quite a lot and I was curious about how good it is” (P1).

Overall, there was a sense that participants were intrigued and interested in the idea of supporting notions of ‘active passengering’, which might allow them to be more engaged with the environment external to the car on a journey.

7.2 Reflective Passengering

Our participants also discussed more reflective modes of passengering. In particular they raised a desire to use our system to *reflect on journeys* after the event: “I think to be able to share with the driver things they might have missed on the journey that were interesting, because they were concentrating too much on the road, might be quite nice” (P8); and “For me, the appeal is more as a story of your journey” (P2).

To achieve this, of course, required some *documentation of the journey*, and again participants saw value in systems similar to ours. “If somebody said, “How was your journey?” When you got home, then you could actually show them. In some ways, you’ve already made the editorial decisions about that storytelling along the way” (P2). This could of course come through the photos captured “it would be amazing to be able to just grab pictures of what you’re looking at. Because so often by the time you’ve got a camera out to take a photo something interesting has passed” (P8); and “If the car could do it for me and if the camera on the car is good enough, that would be pretty majestic” (P3). GPS tracking was also seen as a highly beneficial form of a record, “the exact location of where it happened was really useful” (P8).

7.3 Social Passengering

Beyond notions of post-hoc reflection much of discussion with participants focused on the system’s social potential. For some this revolved around ideas of *being social within the car*, “If I was a passenger, and in the car with somebody else, and I was doing this, I’d be trying to grab their attention all the time, saying, ‘Look at this,’ and probably distracting the driver” (P4). However, some were concerned by the possibly isolating nature of the device “[I would be] less engaged with those inside the car as I will be busy using the screen” (P7).

For other participants, potential in the system came from its possible ability to support **sociality among passengers in different vehicles**: “I’d be interested in other people who had the same viewpoint and system; what sorts of things they annotated, seeing what they search for and what they said about things on their journeys”; “It might be useful, not useful but intriguing, to see how what you see compares to what others see on similar journeys but at different times and that sort of thing” (P1). And of course for many this was simply a desire to share content viewed broadly, “I prefer to use this system to share some memories with my friends or my family, rather than just checking some information” (P5).

Perhaps inevitably, many saw possibilities in the technology for **supporting gaming activities**, “I am just thinking about the sort of car colour spotting game and could you almost have a, ‘play a game’ icon or something and you would tap on the car as it went past to count it” (P8); and “If I can use this interactive car window with other passengers in the car (definitely, every side of the car window has different view and scenery), it would be more playful and make better travel experiences” (P5).

Of course in many of these scenarios of socialised interaction (especially gaming) there would be a need for **supporting multiple users**, which might entail either multi-touch interaction “I think the screen needs to support multi-user touch” (P7) or multiple screens “that would obviously need you to have one of these on each side of the car, if you have some sort of collaborative game” (P8).

There were, therefore, various ways in which passengering was seen to be a socialised activity, which might be expanded by a variety of different kinds of technological intervention.

7.4 Temporality and direct experience whilst passengering

The final considerations for passengering whilst using our system, revolved around the **changing nature of temporality** for the passenger as they engaged with the ‘real world’ through the ‘new’ car window. For many, the temporal constraints of the system (i.e. the ten-second buffer and the jumping forward to the real-time car position) meant that there were frustrations around its use, “I suppose by the time I’d rewound, looked at something, captured what I wanted to and then we’d gone back into real time, I was conscious that every time I did that, I might have missed something in the interval while I had been interacting” (P8).

This pervasive concern for missing out when freezing and rewinding was balanced by the advantages of staying in the moment, “I stay in that moment for longer. It’s not that I just pass by, I’ve extended there at my own pace and I have seen this happening” (P3).

For some just having the capacity to record fundamentally altered the experience, “Knowing that I can go back to somewhere, makes me feel like paying attention to what we’re driving past is potentially more rewarding than it would be to rubberneck to something that’s interesting, that’s just gone past” and, “I think it rewards the interest that you might have normally, in something that would be very transient, here and then gone” (P2).

However, for some of our participants there was a concern over the potentially distancing nature of the experience when using the technology. They were concerned for **the ‘direct experience’ of the world**, “I guess there may be something lost in constantly looking for ‘items of interest’, not experiencing the world as a straightforward stream of experience” (P6); and “I will be busy watching the screen (with its limited view) looking for something interesting and not noticing the external environment as a whole” (P7). For some this was very much an issue of screen-mediated interaction, “If you have to put up with screens in the car that aren’t the same quality that you get from a window, it’s nice to have the experience of being able to look out of the window and see the environment for what it actually is” (P1). This latter point is perhaps the most revealing demonstrating as it does a participant’s explicit belief in an essential quality of the environment external to the car that could somehow be experienced, and which was perturbed by our system. But as we have hopefully demonstrated there were equally interests amongst the participants in the way our technology could positively keep people “in that moment for longer” (P3).

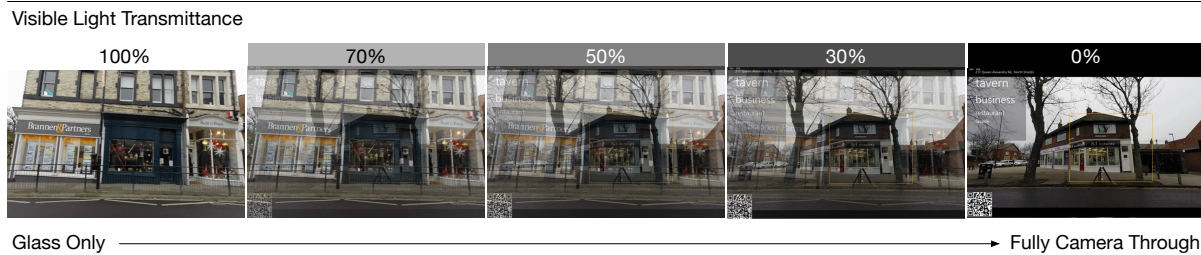


Fig. 9. A simulation of camera see through display. 0% means that the window is just a glass; 100% means that the window is fully covered by a opaque display (i.e., LCD display w/backlit).

8 LIMITATIONS AND LEGAL CONSTRAINTS

Although the video footage we used in our studies was obtained from a camera attached to the rear window of a real car, our approach was based on in-the-lab evaluations. This could be seen as a limitation/weakness of this study. In this regard in-the-wild observations may differ from what we found in-the-lab. For example, some users might possibly report motion sickness due to framerate and/or video latency, and may report difficulties of operation on uneven road-surfaces. Also, an in-the-wild study might possibly derive qualitatively different findings than an in-the-lab study for example based on the time of day that a journey takes place, varying weather patterns and geographical locations. However, a push for more ecological validity from an in-the-wild study might give rise to situational/accidental factors which could obscure the purpose of the user study - detracting attention from an evaluation of the technology concept. Also, early prototype technologies used in real cars, on real roads, pose potentially significant risks of distraction in hazardous situations. In-the-lab studies offer much more practical and safe environments in which these situational/accidental factors can be controlled in which the basic system functionality can be focused on more thoroughly. Even though we could have run this study with a real car without driving, the situation might cause unnatural experience for the participants. Because, there must be a difference between the scene on the screen and around the car. Consequently, it is germane to conduct a series of thorough in-the-lab studies before moving to in-the-wild implementations and evaluations. Video testing is widely acknowledged as a viable technique in a number of areas, including a vast quantity of driving research which utilises simulator studies.

There are various future directions that research and development in this space could take. One area of interest would be to explore interactive car windows for multiple users. In our studies, as a first step, we have focused on the interactive car window system for a single person. This may also limit the scope of our findings. Obviously there are multiple windows within a vehicle and there are possibly multiple people in a car. The side windows on either side of a vehicle are usually reachable only by the person adjacent to the window. This represents an interactional challenge to be addressed. For example, windows could be interacted with remotely through gesture and/or external views from windows could in effect be ‘switched’ from one side of the car to another, using video feeds.

To implement our system in a real car, there are some problems that would need to be overcome. One area concerns legal constraints. Most countries restrict the attachment of items to windows that block the driver’s view. Our system is not an exception; it hinders the driver’s view if attached to the side windows adjacent to the drivers seat (and arguably to any of the passenger windows). Attaching items to a window is functionally equivalent to installing a window tint/sticker. We conducted a review of legislation for installing car window tints in three countries: the US, the UK and Japan [26]. Most of the laws for car window tints make use of a measure of Visible Light Transmission percentage (VLT%). Only five states restrict window tint for rear side windows. Most states (46 states) and countries (including the UK and Japan) allow a rear side window tint under 50 VLT%, and 28 states,

including the UK and Japan allow it under 30 VLT%. Figure 9 shows a simulation of visiblenss of our camera see through display. 0% means that the window is completely made with glass, 100% means the window is fully covered (replaced) by a display. Through the result of the simulation we found that 30 VLT% is workable for our system. Interestingly, 34 out of 51 states in the US allow a tint for front side windows under 30 VLT%. That is, our system may be usable for front passengers (except drivers). Futhermore, in the impending era of autonomous vehicles, legislation in this regard is likely to be revised given the redundancy of the driver and there being no immediate need to secure the driver's view (given that cars will likely use 360 cameras and LIDAR technology to position themselves); all car windows including front/rear windshield could the feasibly be replaced with our camera see through system. Indeed, the rise of autonomous vehicles is fundamentally changing the nature of the car as an inhabited space. Much more consideration should therefore be given to exploring new kinds of interactive in-car experience, and our project has contributed one preliminary example of designing to support more engaging in-car activities based on a detailed understanding of passenger experiences.

9 DISCUSSION AND CONCLUSION

In this paper we have attempted to explore the question of how digital technology might help passengers to interact with the external environment during a car journey. We approached the question through three steps. Firstly, we conducted a scoping study, consisting of a group workshop and associated interviews with six participants to develop a basic understanding of people's experiences and practices of being a car passenger. We used this understanding of their prosaic experiences to develop a set of guiding principles and concepts to help us design a prototype interactive car window system. Secondly, based on the findings developed from the scoping study, we implemented our design for an interactive car window system. Finally, we conducted a user study of the system to understand how people might interact with the external environment through it, and to reflect more deeply on how our intervention might alter the experience of being an in-car passenger. Through the series of studies, we elicited four key themes around the idea of supporting passengers in the car. These four themes address our research question of how digital technology might help people to interact with the external environment during a car journey and have explored the potential for systems such as ours to make passengers more active, more reflective, and more social, in contrast to what they perceived to be the more traditionally passive experience of being a car passenger. These ideas broaden our understanding of what it means to do passengering. Hopefully, herein we have developed a set of advanced notions of passengering that others may find useful to further explore when thinking about the kinds of in-car experience that we should or should not be supporting for car occupants. This has increasing importance as we move towards the adoption of autonomous vehicles in which the role of in-car occupants is likely to drastically change.

Our explorations have also suggested a variety of directions for potential future research and technical development. To support *active passengering*, we might wish to add features to input information into the world. In our previous studies we discussed the possibilities of embedding in-car conversations into locations to share personal experiences with others [27, 28]. In a similar way, we may embed pictures as well as additional information such as text and audio into the world, specifically aiming to crowd-source information about features of the built environment and the landscape which people evidently find curious. Also, to enrich the *social passengering* experience, we might think about how we can both support multiple individual users of a system within the car and their collaboration (something other researchers have considered [11, 32]). There is evidently significant scope for starting to explore how we might productively network autonomous vehicles, not for the mundane considerations of platooning vehicles (as is more commonly considered), but actually for starting supporting both entertainment and information seeking purposes. It is intriguing to think about the possibilities that can come from appropriating the surfaces such as windows within a vehicle when we no longer need to assume that what must be shown is a live

image of the external world. This raises curious possibilities and questions, for example, what might it mean to ‘swap’ a journey with others, so that your driving experience, is essentially of another place?

However, one challenging feature of our analysis that came out very strongly was a desire for ‘direct experience’. Some of our study participants expressed a clear desire for authenticity of the journey experience, and concern about the distancing potential of mediating technology that separated them from the environment. One key challenge here is how we can design systems that do leverage the exciting potential of novel display surfaces in otherwise driverless cars, whilst retaining support for ‘direct experience’ of the journey.

One area in which the issues of direct experience was most evident was the concern about temporality and the problems caused by freezing images whilst travelling, and the associated concern over lost imagery, when the screen caught back up to its real-time view. This was raised by a not insignificant number of participants. Currently, we provide a quick playback of the external scenes as time-lapse images, however, participants were claiming that it was too fast. As there was only a ten-second buffer, if the user interacted with the frozen picture for longer than ten seconds, they would lose a chance to see potentially important or interesting features of the external environment within the time-lapsed images. To overcome this problem, there are some possibilities. In our current implementation, we tentatively set the buffer to ten seconds because of the size limitation of the memory, however, we could potentially expand buffer-time significantly. Also, we might improve the user interaction design of the system. Figure 10 shows an idea suggested by one of our participants. His simple idea is that the system displays a real-time scene on the outside of the clipping area whilst the user is interacting with the clipped object.



Fig. 10. The idea one of our participants suggested.

What is shown above is a very simple idea. What it encapsulates very nicely however, is a balancing of core concerns that passengers expressed. Whilst they wanted to be able to play with the images captured by the system, to explore video footage, to search for information, essentially creating artificial lenses on the external environment, they had a strong desire to maintain a current and active connection to what they articulated as the direct experience of travel. They needed to maintain a continual awareness of where they were in the journey and what was happening around them. This feeds in to the idea of the *active passenger*, in that when we are on a journey we are engaged in a continual flow of experience, and whilst we might wish to insert technology in to this stream of experience, to facilitate a variety of other interactions and diversions, we need to support the capacity for connection to the external environment in a way that *authenticates* direct experience of it. And that is a particularly intriguing challenge.

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